

Project Name:

Fast 1D Coded Aperture X-ray Movie Camera

**FUSION Diagnostics Program Review (Virtual)
March 5, 2021**

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Team Members and Roles

- ▶ Paul Bellan, PI
- ▶ Seth Pree, Postdoc
 - Build PMT-based coded aperture X-ray camera
- ▶ Yi Zhou, Graduate Student
 - Build PIN-diode-based coded aperture X-ray camera

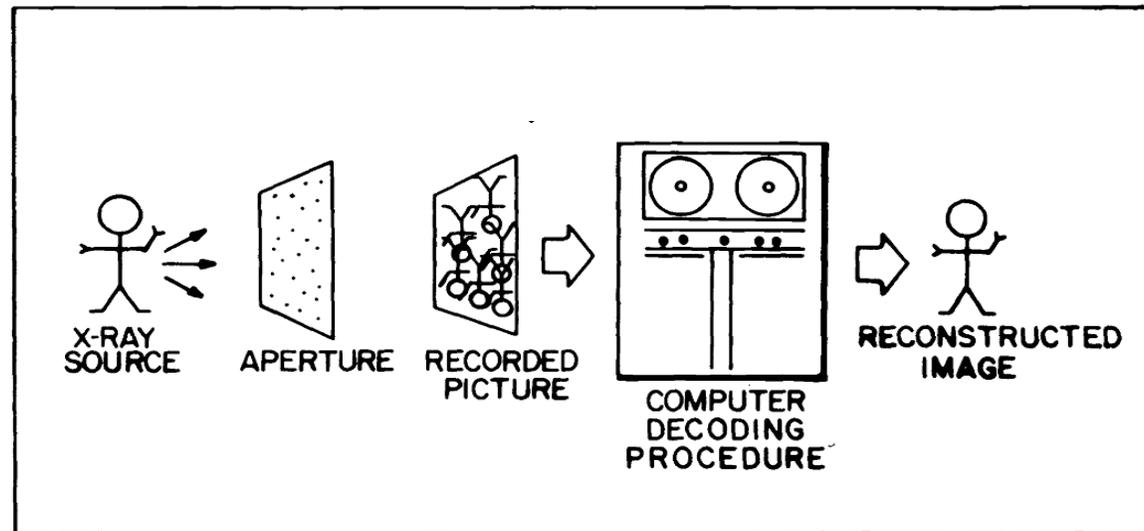
Diagnostic will make 1D movies of X-rays having energy > 5 keV

Spatial resolution up to 128 pixels

- ▶ PMT-based coded aperture camera
 - 128 pixel LYSO scintillator
(LYSO= Cerium doped Lutetium)
 - Coded aperture mask
 - Optical fiber coupler to 128 PMT channels
 - 128 channel 125 MegaSample/s digitizer
 - 40 nanosecond time resolution
 - Will provide streak-camera type image of X-rays
- ▶ PIN-diode-based coded aperture camera
 - 50 channels (now)
 - Each channel has charge sensitive amplifier
 - Detects X-rays as low as 5 keV
 - 1 microsecond time resolution
 - Will provide streak-camera type image of X-rays

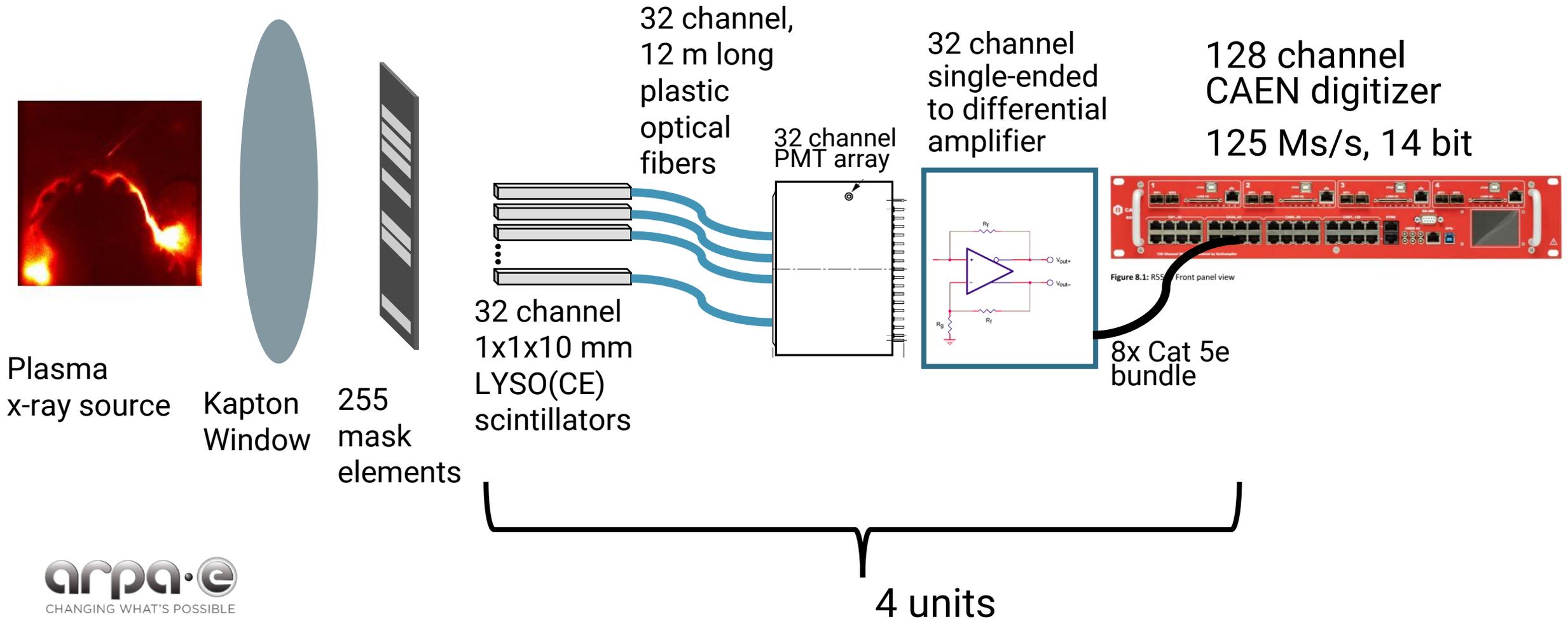
Coded Aperture Imaging Method

- ▶ X-rays cannot be focused by lens or reflected by mirror
- ▶ Only pinhole cameras can make images, but very little radiation gets through
- ▶ Coded aperture is like have N pinholes where N is a large number
- ▶ Get pinhole-like imaging with much more signal



Schematic Diagram of 1D X-ray Coded Aperture (PMT-System)

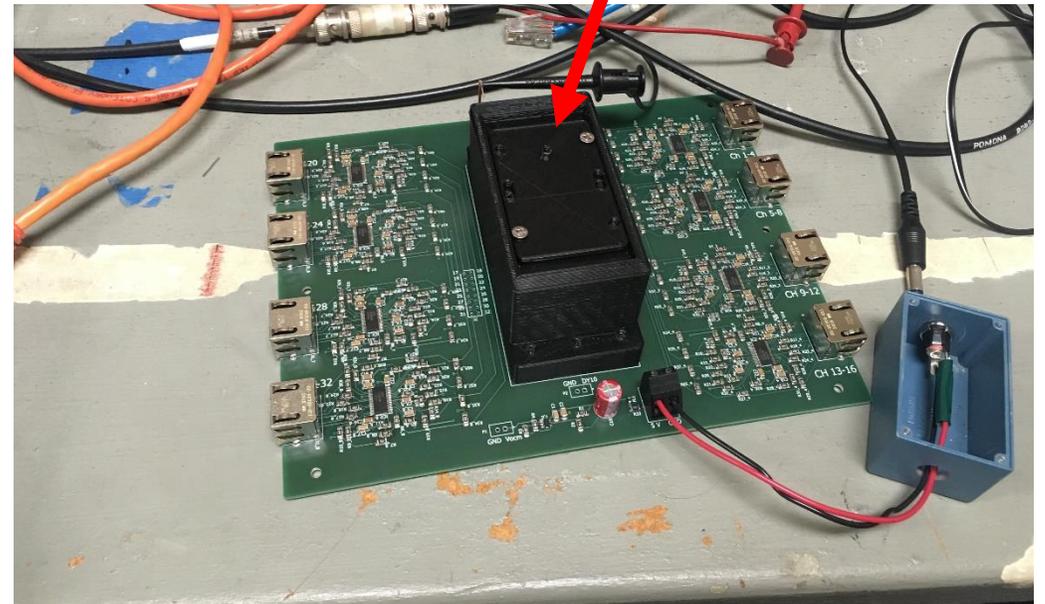
Desire: Image hard x-rays, ~10 cm field of view, ~1mm resolution, >100MS/s,



Status of 32 Channel Amplifier Assembly

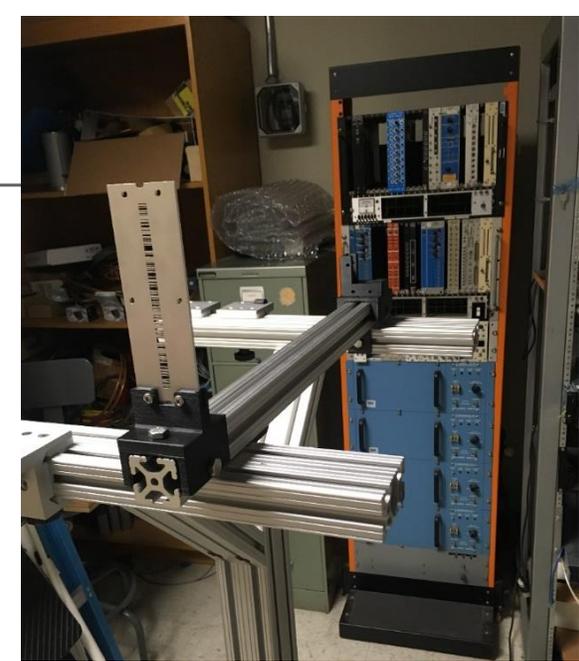
- ▶ converts 32 channels of PMT outputs to differential signal for digitizer
- ▶ 4 assemblies required for 128 channels

32 channel
PMT
housing



Assembly Status

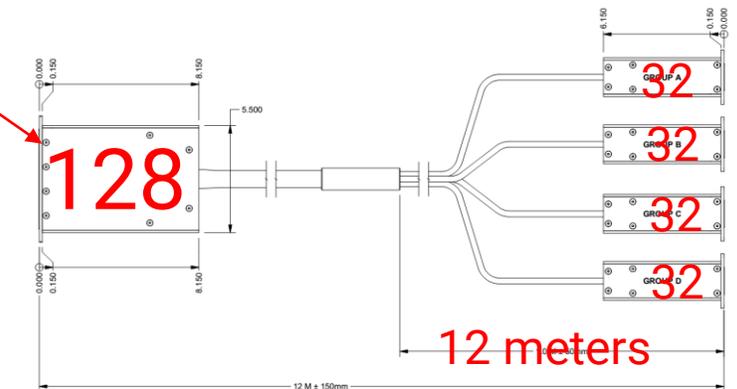
Key Equipment	Status
Digitizer	Arrived, software developed, tested
Custom 128 pixel LYSO scintillator	Arrived, partially tested
32 channel amplifier module with PMT	Designed, assembled, and partially tested
128 fiber bundle with LYSO scint. mounted	Arrived Monday
Coded aperture mask	1 st designs laser cut
Large vacuum window	Preparing tests



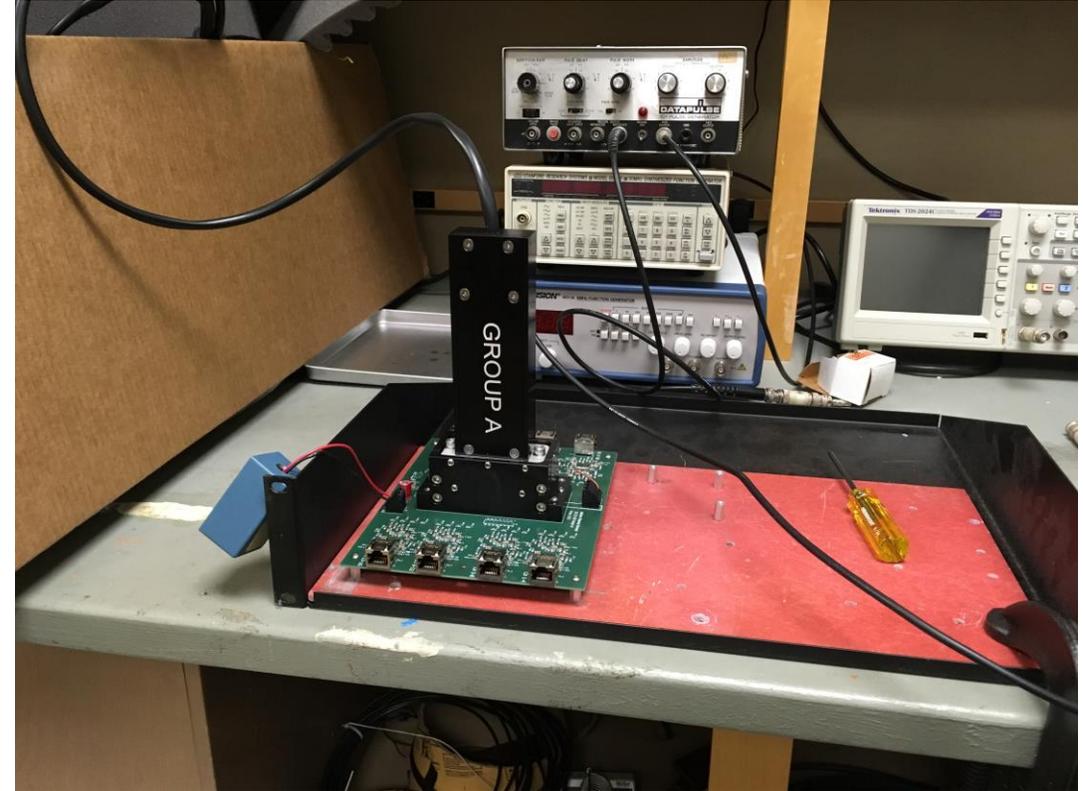
128 pixel LSYO



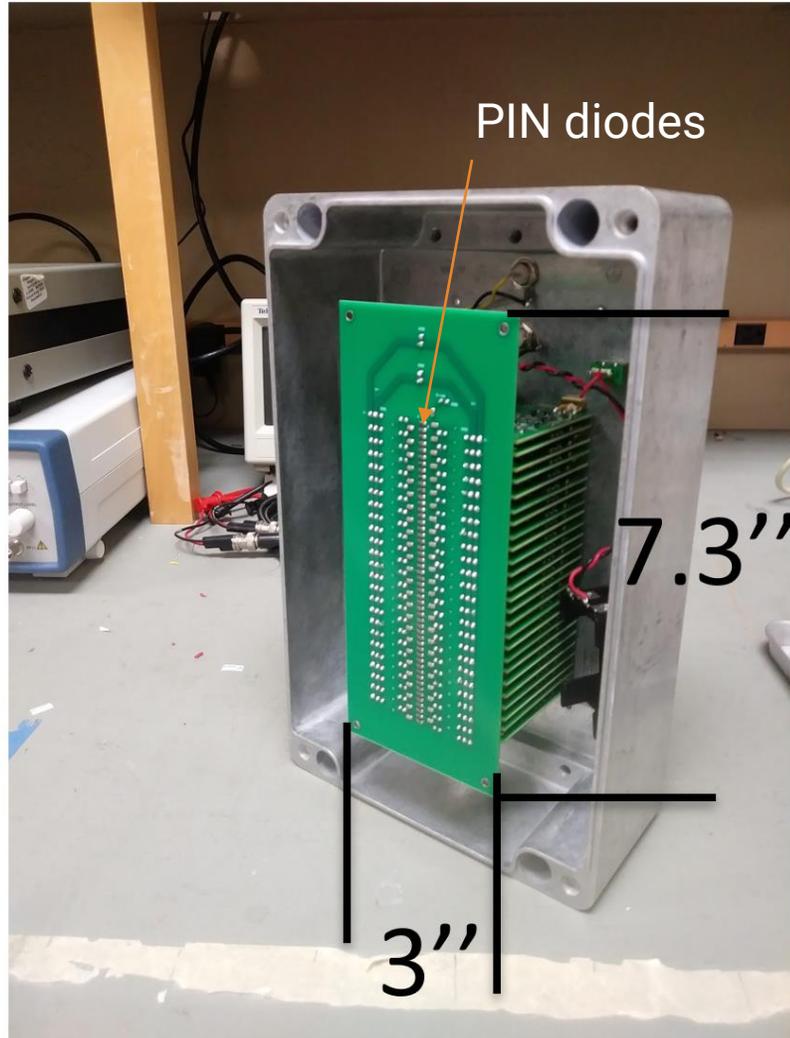
fiber bundle



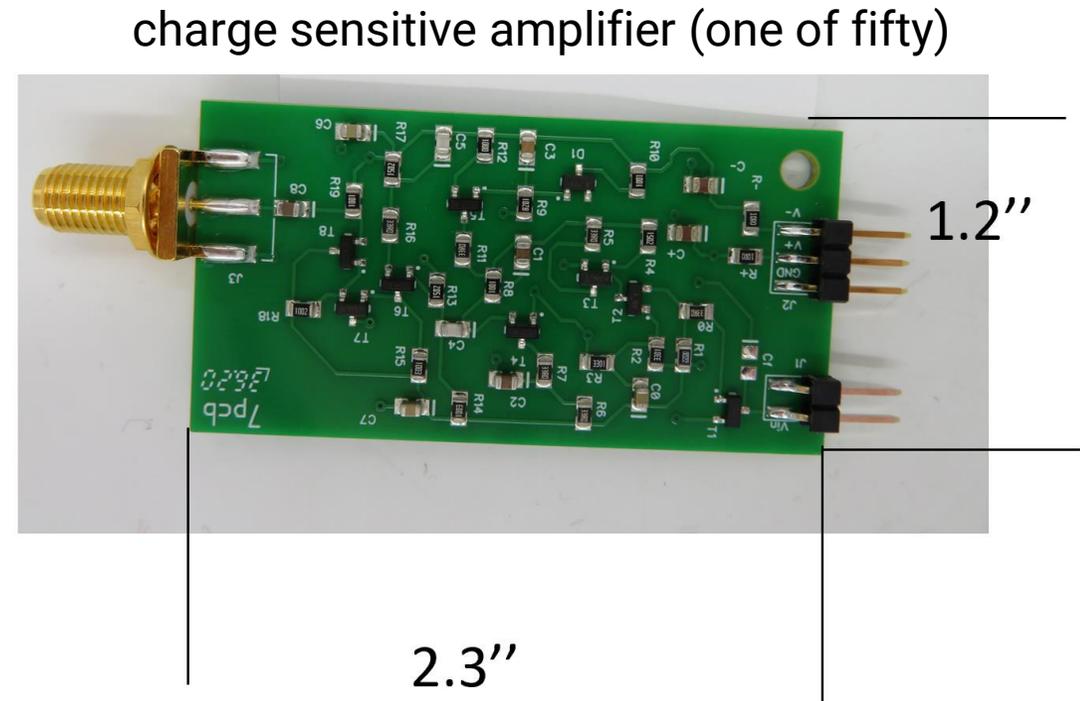
Fiber bundle with LYSO (arrived Monday, March 1)



PIN Diode System



50 channel
PIN diode array
mounted on 50
channels of
charge sensitive
amplifiers



Robust, Portable, Adaptable

PMT-based system

- ▶ Uses portable 128 channel Caen digitizer
- ▶ Digitizer uses commercial CAT-5 connectors instead of expensive, awkward lemo connectors for input
- ▶ Digitizer connects to laptop computer
- ▶ Uses four 32-channel Hamamatsu PMT array module
- ▶ Uses readily obtained semi-custom LYSO scintillators
- ▶ Uses 12 meter long custom fiber optic coupler made by Fiberguide

▶ PIN-diode based system

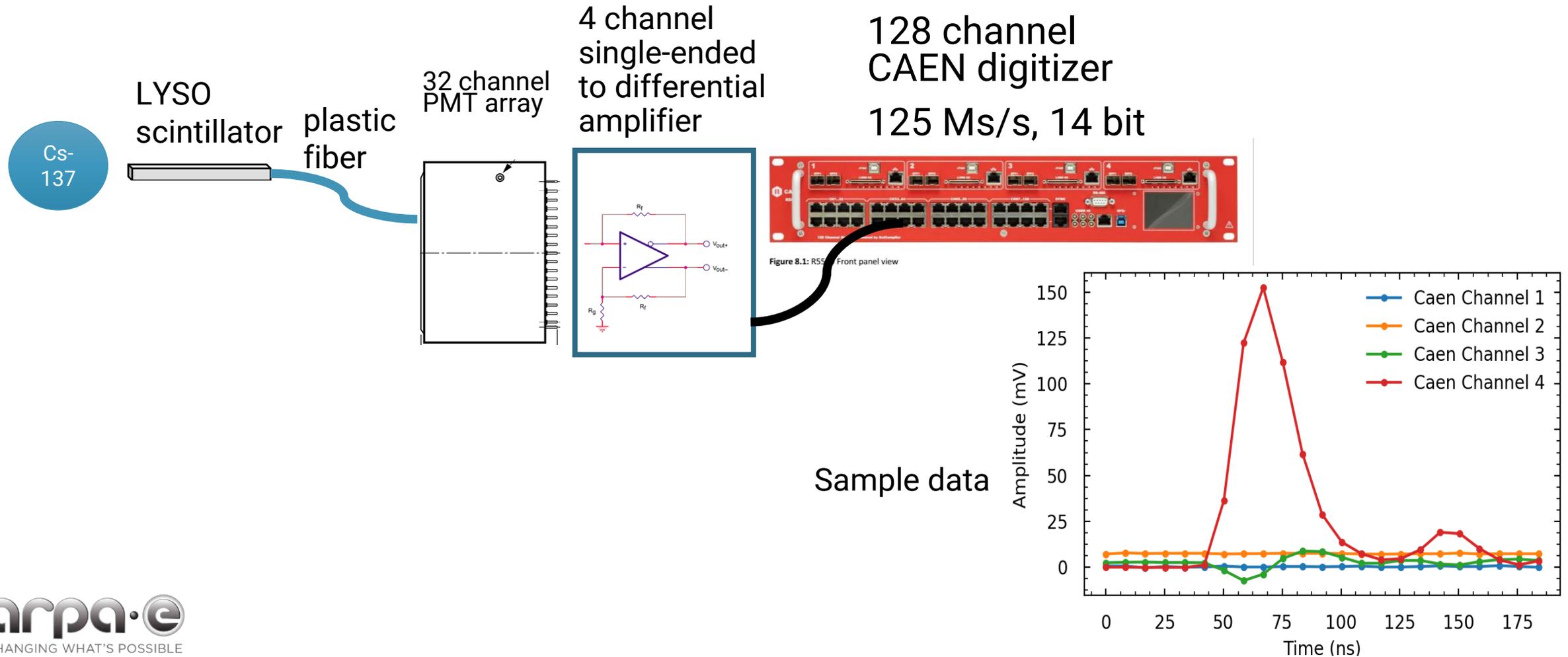
- Uses off-the shelf PIN diodes and electronic components
- Directly connects to digitizer (no fiber cable)
- Low-cost standard circuit board construction, easy to duplicate

Intended Deployments to Fusion Experiments

- ▶ First deploy to ZAP
 - need to make Kapton window, first must test/validate system at Caltech
 - have ZAP flange drawings
- ▶ Second deploy to MIFTI
 - image compression (streak camera)
 - risetime is potential issue
 - could be made faster using different scintillator material, more optimized amplifier

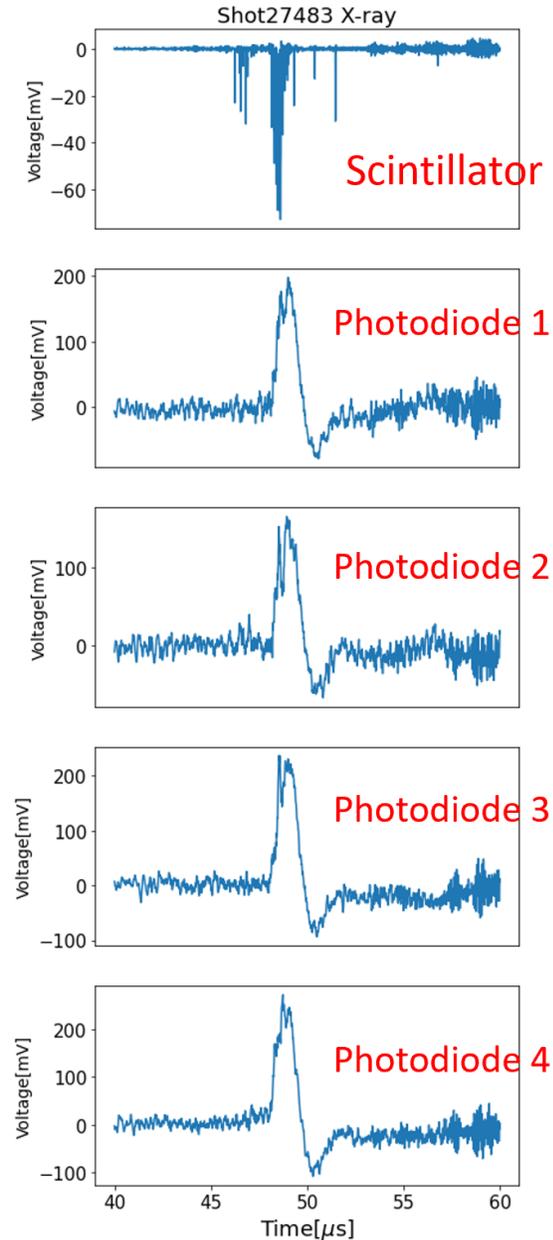
PMT-system Initial Calibration/Test

- ▶ Successfully detected X-ray from Cs-137 calibration source, cosmic rays using LYSO scintillator to single fiber to PMT to digitizer



PIN diode system Initial Calibration/Test

- ▶ Successfully detected 5 keV X-ray from Fe-55 calibration source
- ▶ Successfully detected X-rays from plasma jet experiment



Top trace is plastic Scintillator-PMT for reference

X-ray signals from Caltech plasma jet expt

Plans beyond present program support, other potential “customers”

- ▶ New digitizer is of interest to fusion community
- ▶ We are one of first users of this device
 - Much lower cost per channel than traditional digitizers, \$200/channel
 - 14 bits, 125 MegaSample/second
- ▶ X-ray streak camera operating with 25 MHZ resolution should be of interest
- ▶ Coded aperture provides square root N increase in signal to noise
- ▶ High performance charge sensitive amplifier circuit developed
- ▶ Low-cost components, easily duplicated